

P / REFERENCES OF DESIGN

DESIGN WITH LIVING ORGANISMS. ALTERNATIVE PERSPECTIVES FOR REGENERATIVE ECOLOGIES.

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ABSTRACT | Climate change and natural disasters are causing globally increasing complex issues that require alternative strategies and approaches to design. Addressing the current ecological crisis generates unconventional perspectives that guide research and lead many designers to work in multidisciplinary spaces and collaboration with experts from the biological and natural sciences.

Today we are experiencing the spread of new design practices and approaches such as Biodesign and Regenerative Design, in which, through the integration of biological knowledge into the design process, new research directions and new perspectives are generated for the creation of hybrid artefacts that merge natural and technical systems.

The research initiated in December 2022, conducted at the deMIT 38th cycle PhD, in associated form between the University of Campania “Luigi Vanvitelli” and Luav University of Venice, aims to critically analyse the intersection of design and biology disciplines. The aim is to investigate how resilient products that respect natural ecosystems and promote ecosystem benefits in urban areas can be developed through the use of living materials.

The research focuses on the development of Nature-based Solutions (NbS) and examines how biofabrication processes, mycelium growth on substrates, and the use of algae and plants can be applied to develop regenerative bio-based products. In particular, it investigates the development of responsive products and systems that can adapt to environmental variations and change their properties in response to specific external stimuli.

The research proceeds and plans to proceed following several phases: preliminary analysis, background, study of the state of the art, formulation of the hypothesis, experimentation and observation, and conclusion. The preliminary phase is useful to define the context of intervention, while the background phase focuses on reviewing the existing scientific literature on the topic. To identify the approaches adopted by designers, the collection and analysis of representative case studies will be started.

The research currently envisages defining the scientific framework of Biodesign practices and developing a BioDesign Tool characterised by a multi-level structure. This tool aims to support designers in the use of biofabrication techniques and facilitate the application of living materials for the development of products capable of reacting and adapting to complex situations in changing environments.

The current hypothesis envisages the creation of an open and scalable conceptual system that will make it possible to organize and make use of the available information. This is aimed at facilitating designers to recognise the specific characteristics of living materials and to design products capable of contrasting changing environmental conditions.

Following the formulation of the hypotheses, the research involves an experimentation and evaluation phase using workshops and tests.

The main objective is to collect data on the application possibilities of the developed model in the design context to formulate conclusions.

These tools could enable designers to acquire skills in the new approach based on cooperation with natural systems and regeneration, overcoming the traditional approach based on the exploitation of resources

1. Introduction: a Necessary Transition

In the current context, it is increasingly evident that there is a necessity to explore new directions of research and to develop actions that aim to effectively address environmental challenges and counter the complexity of ecological issues.

Human activities have caused a series of transformations that impact the entire planet and generate a considerable disruption of ecological dynamics and balance.

The amount of material produced by human activities, known as 'anthropogenic mass,' exceeded for the first time in 2020 the entire living biomass on Earth, which includes plants, bacteria, fungi, archaea, protists, and animals (Elhacham et al., 2020).

To successfully face the challenges of climate change, biodiversity loss, and ecosystem destruction in the coming decade (WEF, 2020), the European Union is implementing policies and plans for ecological transition. In the European Green Deal (European Commission, 2019), development plans converge that set a reference in the resistance to climate change.

Through specific strategies and policies such as the EU Biodiversity Strategy 2030 (European Commission, 2021a) or the EU Strategy on Adaptation to Climate Change (European Commission, 2021b), European governments aim to promote biodiversity and make cities more resilient to climate change.

Furthermore, mitigation and adaptation actions are promoted through the development of solutions that integrate nature into design through Nature-based Solutions (NbS) (EEA, 2021), which are a useful tool to pursue objectives such as the implementation of climate change mitigation actions (European Commission, 2015).

2. Background: Holistic Design Approaches

In recent decades, we have seen a redefinition of the paradigms of sustainability towards a perspective that aims to promote human well-being as well as ecological systems. Current post-anthropocentric visions (Wakkary, 2021) emphasise the creation of prolific systems where progress and improvement are intrinsically linked to the promotion of the health of both human communities and natural ecosystems. In this context, sustainability is no longer seen as a mere adaptation to available resources but as an active commitment to the creation of enabling conditions for interspecies coexistence in the same ecosystem (Latour, 2022).

These attitudes, which encourage an approach of mutual interspecies interdependence (Tsing, 2015), help to promote a deeper connection between society, designed technical artefacts, and the natural environment (Haraway, 2016).

Emerging concepts of sustainability promote a significant transition from an anthropocentric to a more holistic and interconnected perspective through practices that not only mitigate negative impacts on the environment but also actively contribute to the regeneration and empowerment of ecosystems.

The concept of Regenerative Design (Lyle, 1996) represents an approach that attempts to promote material and technological progress toward building systems that prosper in symbiosis with their environment.

This approach aims to guide the development of adaptive regenerative strategies in specific contexts (Gibbons, 2020) to contribute to the long-term well-being of the environment and living systems.

It also (Figure 1.) draws inspiration from the innate capacity of natural systems for self-healing and self-organisation (Mang & Reed, 2020). The methodology addresses the functioning of living systems, attempting to replicate resilience, flexibility, and adaptability. In this sense, biological systems, characterised by adaptive and reactive behaviours developed over time (Haeckel, 1904) and response mechanisms to external stresses and adverse actions (Haeckel, 1866), represent a design paradigm to be investigated to produce artefacts with responsive performance.

To address the complex challenges related to sustainability and the production of sustainable materials, the discipline of design is moving beyond conventional confines, searching for inspiration in the biological models and metabolic processes of nature. To develop new experimental, design, and production scenarios (Oxman, 2016), new practices such as Biodesign (Myers, 2012) emerge, combining design principles with biology, involving living organisms directly in the design process (Myers & Antonelli, 2012).

These are highly collaborative practices (Ito, 2016) that promote multidisciplinary approaches and integrate knowledge and technologies from other disciplines, such as materials engineering and natural and biological sciences, with design (Oxman et al., 2015).

The convergence of design and biology opens new perspectives for innovation and leads designers to access scientific laboratories and equipment (Willet, 2021) and to acquire fundamental skills and knowledge for the integration of biological principles into design (Langella, 2019; Perricone, 2021). In the last decade, there have emerged several research centers, such as the Hybrid Design Lab, the Material for Transitions (MaDe/Trans), the Wet Lab at the MIT Media Lab, the Waag Society's Open WetLab, the Biodesign Lab, the Atelier Luma, the Biofilia-Base for Biological Arts, the SVA Bio Art Lab, the SilkLab and others, where individuals or organisations come together to collaborate and develop projects through the use of biomaterials and living organisms.

Many designers adopt do-it-yourself (DIY) practices to develop new designs and experiment with alternative techniques. Designers operate in temporary spaces or community bio-workshops, using their design skills to create the tools and machines needed to promote advanced, distributed, and shared production processes (Rognoli et al., 2015).

There is an increasing publication of open-source distributed learning educational programmes that promote recipes and models for the collaborative production of biomaterials through the use of low-tech tools (Ribul, 2013; Duenn, 2018)

At the same time, there is a diffusion of biotechnology movements that aim at the active involvement of ordinary citizens in biotechnology movements, dissemination, and democratisation of biology. Among the community, DIYbio Labs and online bio-networks can be found BioClub, Bioartlab Laboratories Foundation, Biohackerspace, DIYbio, Biologigaragen, DIYbio Belgium, DIYbiosphere, Dutch DIY Bio Group and others (Priola & Manfroni, 2024).

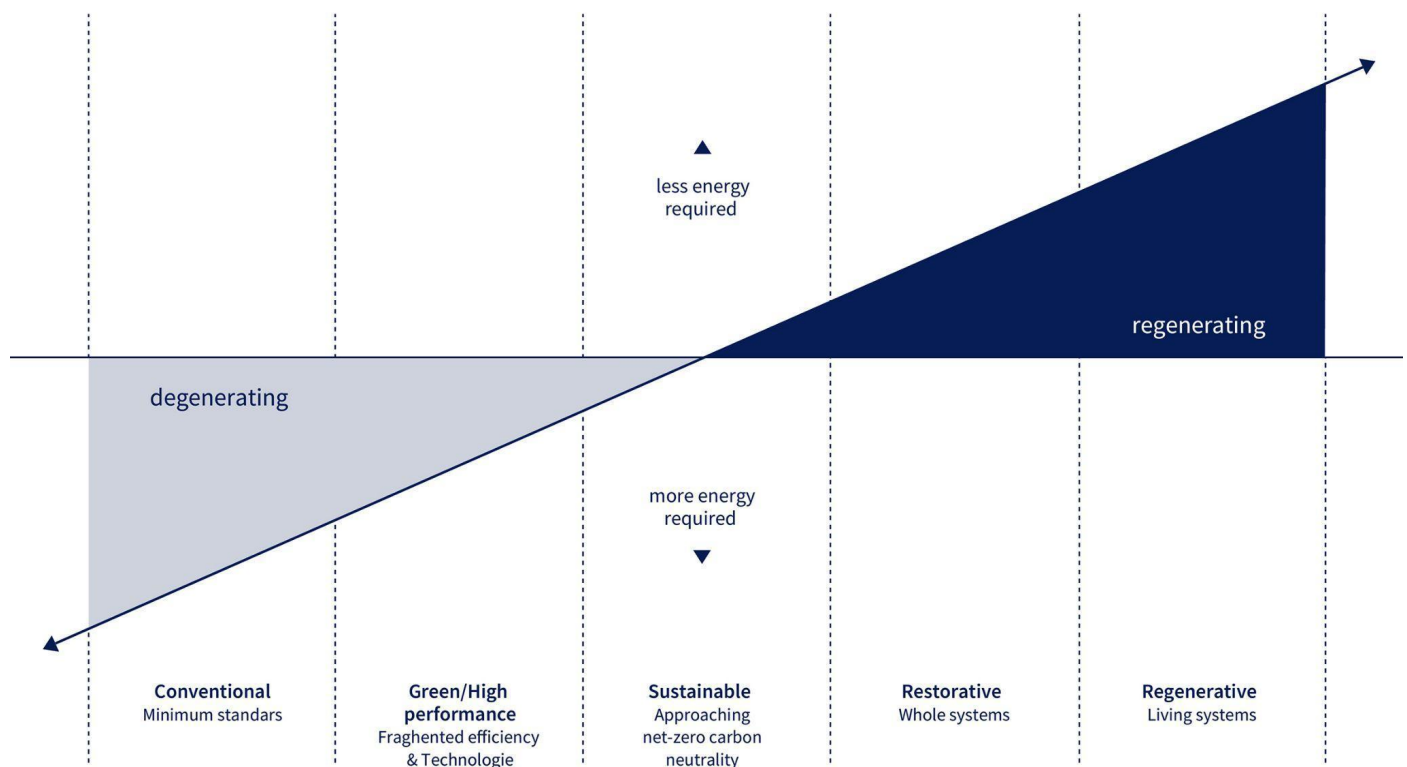


Figure 1. The trajectory of Ecological Design, © Regenesi Group, in (Mang & Reed, 2020).

3. Research Methodology

The research promotes a theoretical and practical change and promotes a design vision based on the interconnection and interdependence between all forms of life and the natural environment. It aims to

examine the intersection between design and biology, with a particular interest in the role of design as a driver of innovation in the development of new sustainable scenarios.

To start a critical reflection on the most recent regenerative research and experimentation practices in Biodesign, this study combines desk and field research methods, which are fundamental to improving the understanding and validity of existing data and results obtained in the different stages of research.

The research focuses on the following primary and secondary questions:

- RQ1. Is it possible to collaborate with living systems and integrate them into the design process to develop products that are biocompatible with changing ecosystem conditions?
- RQ2. Through the adoption of biofabrication techniques, will designers be able to facilitate the development of responsive and regenerative products?

To answer the research questions, it was hypothesised a research approach combining qualitative and quantitative methods, based on the development of six different phases (Table 1.).

Research phases 1, 2, and 3 (Preliminary Analysis; Background; State of the Art) provided an in-depth understanding of biodesign practices in Biodesign, Regenerative Design, and Nature-based Solutions (NbS). The exploratory Desk research approach involved the synthesis of documentary sources, while the literature review consolidated knowledge on relevant topics. The classification and analysis of case studies were crucial to understanding the challenges and opportunities related to the use of biofabrication processes in design.

In the next phase, it is expected to conduct practical experimentation with the prototyping of growth substrates under simulated conditions. Phase 4 (Hypotheses) will focus on the formulation of hypotheses and the development of a BioDesign Tool to deal with complexity in the creation of biofabricated products. Phase 5 (Experimentation and Observation), through workshops and tests, aims to validate the hypotheses by experimenting with solutions in structures that explore the interactions between bio-science and design. Finally, phase 6 (Conclusion) focuses on the discussion of the results that emerged during the research.

Table 1. Methodological approach and research phases.

Preliminary analysis	Context, scope of intervention, questions and research method
Background	Theoretical context framework and review of the Biodesign and Regenerative Design literature
State of art	Classification and analysis of case studies, biofabrication processes, prototyping of living materials substrates and testing in a controlled environment
Hypothesis	Formulation of hypotheses on the phenomenon, development of BioDesign Tool
Experimentation and observation	Experimental verification BioDesign Tool
Conclusion	Processing and delivery of research output

4. State of Art: Living and Regenerative Matter

In recent times, designers have become increasingly interested in investigating new biofabrication techniques to develop compostable and biodegradable materials (Collet, 2017). Bio-based materials (Figure 2.) include living materials, which involve the integration of living organisms and represent alternatives to materials made from fossil sources (Collet, 2021). Organisms such as algae, mycelium, and plants, which are used in these processes, are renewable, compostable, and biodegradable (Trebbi, 2021) and therefore offer new ecological perspectives in product design and production.

In recent years, designers have experimented with project possibilities through the application of alternative biofabrication methods based on living organisms (Cantucci, Ferrara & Lucibello, 2014; Karana et al., 2018; Karana et al., 2023). To identify the relationships and examine the methodological approaches adopted by designers in their research with biofabricated materials, the research identified and analysed international case studies developed since 2010. Specifically, the aim is to provide an overview of the various methodologies adopted in this context and to explore the role that designers play in the use of living materials.

The general objective is to provide an overview of the state of the art by presenting concrete examples and to offer an in-depth interpretation of trends and opportunities. The exploratory approach is based on a desk. Analysis of existing data, which will be organised in a dataset for a more efficient reading of the results. In this specific research phase, there were explored three of the most predominant methods of biofabrication of materials. Example cases were identified for each of the following material categories: algae, mycelium, and plants (Priola 2024). In recent years, algae have emerged as a promising alternative for the creation of products and materials, with examples such as the Algae Platform, Textile Lab, Colour Geographies, and Local Bioplastics developed by Atelier Luma. EcoLogicStudio (Pasquero & Poletto, 2020) contributed to projects such as HORTUS XL Tree.ONE, BIO.tech HUT (Figure 3.) and Photo.Synth.Etica. Plants are the basis of innovative projects such as Microgreen Shoe by Stella Harry Lee (Figure 4.), Rootfull by Zena Holloway, Biolace by Carole Collet, and InterWawe by Diana Scherer.

Mycelium is used to join waste organic fibers. Mogu developed sound absorbing panels, Studio Eric Klarenbeek & Dros the Mycelium Project Print and Grow (Figure 5.), Atelier Luma the Myco Structure, Jonas Edvard the Mycelium: MYX, Sebastian Cox and Ninela Ivaniva the Mycelium+Timber.

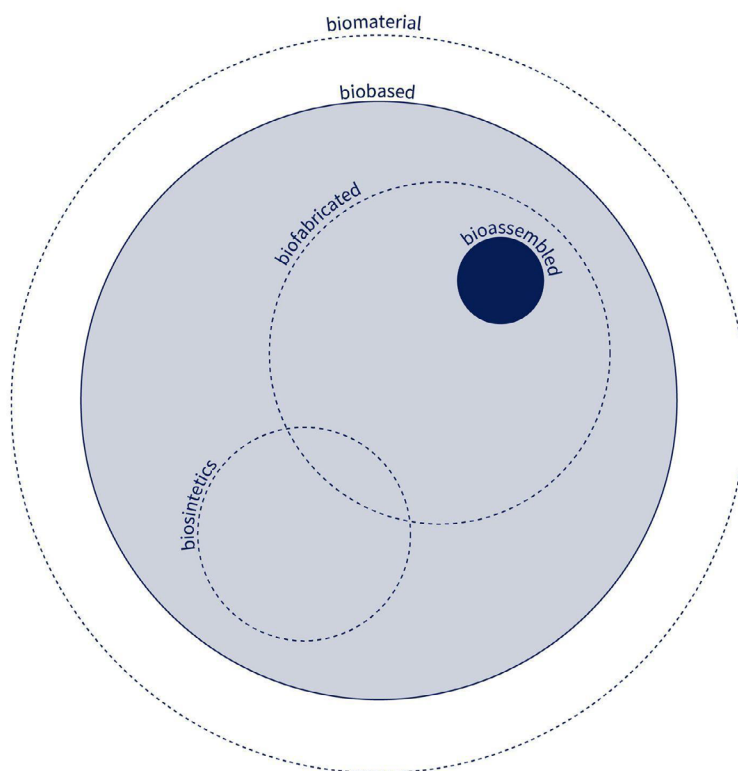


Figure 2. Bio Material Technologies scheme (Lee et al., 2019). Provides a set of terms related to biomaterials and their main production technologies.



Figure 3. BIO.tech HUT, ecoLogicStudio, EXPO 2017 Astana.



Figure 4. Microgreen Shoe, Stella Harry Lee, 2022.

5. Conclusions: Current Results, Future Steps, and Expected Outputs

Currently, the doctoral research, which started in December 2022, has completed the phases of reference literature review and classification and analysis of representative case studies, which have enabled the identification of theoretical and methodological aspects related to Biodesign. The future research phases planned are prototyping living materials substrates and testing in a controlled environment, which is necessary to obtain data useful for the development of the BioDesign Tool. The research currently aims to define the scientific framework of Biodesign and provide a broad overview of the most relevant contemporary practices on the application of biofabrication techniques. Furthermore, it aims to develop support tools for designers in the field of creating regenerative products using living materials. The creation of these tools could provide designers with new skills and promote an approach based on cooperation with natural systems. The application of regenerative strategies in artefact development involves relevant considerations. To effectively address current design challenges while providing benefits for society and biodiversity, two crucial aspects in particular emerge.

The first implication concerns the need to take a multidisciplinary view in analysing phenomena and developing design solutions. This requires the adoption of new methodologies and shared operational tools in the development of Nature-based Solutions (NbS) and responsive products aimed at protecting and recovering ecosystems.

The second aspect concerns the consideration of the time factor, which means the period during which the outcomes of the project actions are expected to manifest themselves. To address the current emergencies and produce positive impacts in the medium and long term, it becomes essential to intensify project actions. These should not only aim to mitigate negative impacts but also enhance the regenerative capacities of the systems being addressed. This proactive approach prefigures a clear change of vision from the conventional approaches used in the design process, encouraging the development of solutions that can contribute positively to the future well-being of humans and natural systems.

References

- Priola, C. M. (2024). Design and living organisms: Grow-made processes of biocompatible materials. In F. Tosi, C. Germak, F. Zurlo, Z. Jinyi, M. Pozzatti Amadori, & M. Caon (Eds.), *For Nature / With Nature: New sustainable design scenarios* (Springer Series in Design and Innovation). http://dx.doi.org/10.1007/978-3-031-53122-4_26
- Priola, C. M., & Manfroni, M. (2024). DIYbio community e attivismo locale: Come gli approcci collaborativi promuovono l'innovazione nel biodesign. In *Criticapratica: Per una critica della normalità: Nuove visioni e paradigmi progettuali*. Symposium conducted at Università di Genova, DAD Dipartimento Architettura e Design, 29 November, Genova, Italy.
- Catucci, S., Ferrara, M., & Lucibello, S. (2014). *Materia primordiale e Growing design*.
- Collet, C. (2017). *Designing for the Biocentury*. Central Saint Martins, Platform Theatre.
- Collet, C. (2021). Designing our future bio-materiality. *AI & Society*, 36, 1331-1342. <http://dx.doi.org/10.1007/s00146-020-01013-y>
- Dunne, M. (2018). *Bioplastics Cook Book: A catalogue of bioplastic recipes*. FabTextiles, Fab Lab Barcelona. <http://fabtextiles.org/bioplastic-cook-book/>
- EEA European Environmental Agency. (2021). *Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction* (Report No. 01/2021). <https://www.eea.europa.eu/publications/nature-based-solutions-in-europe>http://dx.doi.org/10.1163/9789004322714_cclc_2021-0190-608

- Elhacham, E., Ben-Uri, L., Grozovski, J., Bar-On, Y. M., & Milo, R. (2020). Global human-made mass exceeds all living biomass. *Nature*, 588(7838), 442-444. <http://dx.doi.org/10.1038/s41586-020-3010-5>
- European Commission. (2015). *Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-naturing Cities: Final Report of the Horizon 2020 Expert Group on 'Nature-based Solutions and Re-naturing Cities.'* Publications Office of the European Union. <https://data.europa.eu/doi/10.2777/479582> <http://dx.doi.org/10.3030/730426>
- European Commission. (2019). *The European Green Deal*. European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
- European Commission. (2021a). *EU Biodiversity Strategy for 2030: Bringing nature back into our lives*. https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en http://dx.doi.org/10.1163/9789004322714_ccllc_2020-0164-0816
- European Commission. (2021b). *Forging a climate-resilient Europe - The new EU Strategy on Adaptation to Climate Change*. https://climate.ec.europa.eu/eu-action/adaptation-climate-change/eu-adaptation-strategy_en http://dx.doi.org/10.1163/9789004322714_ccllc_2020-0164-0816
- Gibbons, L. V. (2020). Regenerative—The new sustainable? *Sustainability*, 12(13), 5483.
- Haeckel, E. (1866). *Generelle Morphologie der Organismen: Allgemeine Grundzüge der organischen Formen-Wissenschaft, mechanisch begründet durch die von Charles Darwin reformierte Descendenz-Theorie* (Vol. 1 & 2). de Gruyter. <http://dx.doi.org/10.1515/9783110848281>
- Haeckel, E. (1904). *The Wonders of Life: A Popular Study of Biological Philosophy*. Watts.
- Haraway, D. (2016). *Staying with the Trouble: Making kin in the Chthulucene*. University of Chicago Press. <http://dx.doi.org/10.2307/j.ctv11cw25q>
- Ito, J. (2016). Design and science. *Journal of Design and Science*, 1.
- Karana, E., Blauwhoff, D., Hultink, E. J., & Camere, S. (2018). When the material grows: A case study on designing (with) mycelium-based materials. *International Journal of Design*, 12(2), 119-136.
- Karana, E., McQuillan, H., Rognoli, V., & Giaccardi, E. (2023). Living artefacts for regenerative ecologies. *Research Directions: Biotechnology Design*, 1, e16. <http://dx.doi.org/10.1017/btd.2023.10>
- Langella, C. (2019). *Design e scienza*. ListLab.
- Latour, B. (2022). *Dove sono? Lezioni di filosofia di un pianeta che cambia*. Einaudi Editore.
- Lee, S., Congdon, A., Parker, G., & Borst, C. (2020). *Understanding 'Bio'material Innovations: A primer for the fashion industry*. Biofabricate & Fashion for Good.
- Lyle, J. T. (1996). *Regenerative Design for Sustainable Development*. John Wiley & Sons.
- Mang, P., & Reed, B. (2020). Regenerative development and design. In *Sustainable built environments* (pp. 115-141). http://dx.doi.org/10.1007/978-1-0716-0684-1_303
- Myers, W. (2012). *Bio design*. Museum of Modern Art.
- Myers, W., & Antonelli, P. (2012). *Bio design: Nature, science, creativity*. Thames & Hudson Ltd.

Oxman, N., Ortiz, C., Gramazio, F., & Kohler, M. (2015). Material ecology. *Computer-Aided Design*, 60, 1-2. <http://dx.doi.org/10.1016/j.cad.2014.05.009>

Oxman, N. (2016). *Age of Entanglement*. MIT Media Lab, MIT Press.

Pasquero, C., & Poletto, M. (2020). Deep Green. *Topos*, 112, 24-30.

Perricone, V. (2021). Biologia 4.0: L'intersezione tra il disegno industriale e la ricerca biologica nell'era 4.0. In *FRID 2019 – Confini e Contesti: La doppia prospettiva della ricerca in design* (pp. 119-132).

Priola, C. M. (2024). Design and living organisms: Grow-made processes of biocompatible materials. In F. Tosi, C. Germak, F. Zurlo, J. Jinyi, M. Pozzatti Amadori, & M. Caon (Eds.), *For Nature / With Nature: New sustainable design scenarios* (Springer Series in Design and Innovation). http://dx.doi.org/10.1007/978-3-031-53122-4_26

Priola, C. M., & Manfroni, M. (2024). DIYbio community e attivismo locale: Come gli approcci collaborativi promuovono l'Innovazione nel Biodesign. In *Criticapratica: Per una critica della normalità: Nuove visioni e paradigmi progettuali*. Symposium at the Università di Genova, DAD Dipartimento Architettura e Design, 29 November, Genova, Italy.

Ribul, M. (2013). *Recipes for material activism*. <https://www.miriamribul.com/recipes-for-material-activism>

Rognoli, V., Bianchini, M., Maffei, S., & Karana, E. (2015). DIY materials. *Materials & Design*, 86, 692-702. <http://dx.doi.org/10.1016/j.matdes.2015.07.020>

Trebbi, L. (2021). Evolving matter: Nuovi approcci progettuali nell'era della biofabbricazione. In *FRID 2019: La doppia prospettiva della ricerca in design* (pp. 105-118). Bembo Officina Editoriale.

Wakkary, R. (2021). *Things We Could Design: For more than human-centered worlds*. MIT Press. <http://dx.doi.org/10.7551/mitpress/13649.001.0001>

WEF – World Economic Forum. (2020). *The Global Risks Report 2020*. <https://www.weforum.org/publications/the-global-risks-report-2020/>

Willet, J. (2021). BIOLOVE: Designing hybrid laboratories for creative research at INCUBATOR Art Lab. *Arts Imagining Communities to Come*, Cumulus Association, 8-11 November, Guayaquil, Ecuador.

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